REMARKS

Entry of the foregoing, reexamination and reconsideration of the subject application are respectfully requested in light of the amendments above and the comments which follow.

Prior to entry of the present response, claims 1-30, 32-41 and 43-71 were pending. Claims 65-70 have been withdrawn as being directed to a non-elected invention. By the present response, claim 72 has been added, claims 1, 36, 37, 49, 52, 53, 64 and 71 have been amended, and claims 33, 50 and 51 have been canceled. Thus, upon entry of the present response, claims 1-30, 32, 34-41, 43-49 and 52-72 remain pending and await further consideration on the merits. Claims 65-70 remain withdrawn.

Support for the foregoing amendments can be found at least at the following locations in the original disclosure: paragraph [0045]; paragraph [0055]; and the original claims.

CLAIM REJECTIONS UNDER 35 U.S.C. §112

Claims 36-38 stand rejected under 35 U.S.C. §112, on the grounds set forth in the previous Official Action. By the present response, claims 36 and 37 have been amended in a manner which is believed to address the above-noted grounds for rejection, without narrowing the scope thereof. Thus, reconsideration and withdrawal of the rejection is respectfully requested.

CLAIM REJECTIONS UNDER 35 U.S.C. §103

Claims 1-3, 10-11, 15, 20-21, 23, 26-28, 32, 39-41, 43-51 and 71 stand rejected under 35 U.S.C. §103(a) as being obvious over U.S. Patent No. 5,457,343 to Ajayan et al. (hereafter "*Ajayan et al.*") in view of U.S. Patent No. 5,698,175 to Hiura et al. (hereafter "*Hiura et al.*") and further in view of the article entitled "Novel Experiments with Carbon Nanotubes: Opening, Filling, Closing and Functionalizing Nanotubes" by B. C. Satishkumar et al. (hereafter "*Satishkumar et al.*) on the grounds set forth on pages 2-5 of the Official Action. This rejection is respectfully traversed.

The present invention relates to methods of intercalating a nanostructure or nanotube containing material with a foreign species thereby causing the material to exhibit one or more of the following: reduction of the work function; reduction in the threshold electrical field for electron field emissions; conversion of the semiconducting material to a metal; an increase in the electrical conductivity; an increase in the electron density of state at the Fermi level; and an increase in the electron field emission site density. Since the techniques of the present invention lead to alkali metals or other foreign species which are sealed within nanotubes or other nanostructure-containing materials, these enclosed structures are stable in air and other environments, which is not necessarily the case for the foreign species contained therein. Alkali metal and other foreign species can possess a high sensitivity to the environment, thus posing problems in their incorporation into materials.

The structures formed according to the principals of the present invention, wherein foreign species are intercalated within the nanostructure materials, charge transfer takes place between the two, whereby the resulting materials having lower electronic work

functions values and higher densities of states at the Fermi electron level. In addition, because of the above-mentioned charge transfer phenomena, the enclosed structures which typically contain both semiconducting and metallic material can become all metallic in nature after the intercalation procedure performed according to the principals of the present invention has been performed.

A method performed according to the principals of the present invention is set forth in amended claim 1. Amended claim 1 recites:

> *1. A method of manufacturing a material comprising:*
> *(a) producing raw nanostructure or nanotube-containing material comprising closed structures;*
> *(b) purifying the raw material;*
> *(c) processing the purified material thereby forming openings in the closed structures;*
> *(d) introducing a foreign species comprising electron donors or electron acceptors into at least some of the openings;*
> *(e) varying at least one of electronic work function, electronic density of state at the Fermi Level, and electrical conductivity of the material by controlling the amount of foreign species introduced at step (d); and*
> *(f) closing the openings by forming passivation layers, thereby forming capsules filled with the foreign species.*

According to another aspect, a method performed according to the principals of the present invention is set forth in amended claim 49. Amended claim 49 recites:

> *49. A method of reducing electronic work function, reducing the threshold voltage for field emission, converting semiconducting behavior to metallic behavior, increasing the electron density state at the Fermi level, and increasing electron emission site density, of carbon nanotube-containing material, the method comprising:*
> *(a) forming openings in the carbon nanotube-containing material by milling;*

(b) introducing a foreign species comprising an alkali metal, an alkaline earth metal, a mixture of alkali metals, a mixture of alkaline earth metals, or a mixture or alkali and alkaline earth metals, into at least some of the openings; and

(c) closing the openings by forming passivation layers, thereby forming carbon nanotube capsules filled with the foreign species.

According to a further aspect, a method defined according to the principals of the present invention is set forth in claim 53. Claim 53 recites:

53. A method of manufacture comprising:
(a) producing vertically oriented carbon nanotubes on a support surface;
(b) applying an insulating layer;
(c) opening tops of the nanotubes;
(d) introducing a foreign species into the open tops and into interior spaces of the nanotubes;
(e) closing the open tops of the nanotubes by forming passivation layers; and
(f) activating the filled nanotubes.

According to yet another aspect, a method performed consistent with the principals of the present invention is embodied in amended claim 71. Amended claim 71 recites:

71. A method of manufacturing a material comprising:

(a) producing raw nanostructure or nanotube-containing material comprising closed structures;

(b) purifying the raw material;

(c) processing the purified material thereby forming openings in the closed structures;

(d) introducing a foreign species comprising electron donors or electron acceptors into at least some of the openings in an amount sufficient to provide the material with an electronic work function of less then 5 eV; and

(e) closing the openings, thereby forming capsules filled with the foreign species.

Neither *Ajayan et al.*, *Hiura et al.*, or *Satishkumar et al.* disclose, or suggest, alone or in combination, those features required by the presently claimed invention.

As readily apparent from the above, claim 1 requires, *inter alia*:

> varying at least one of the electron work function, electronic density of state at the Fermi level, and electrical conductivity of the material by controlling the amount of foreign species introduced at step (d).

Similarly, the method defined by amended claim 71 requires, *inter alia*:

> introducing a foreign species comprising electron donors or electron acceptors into at least some of the openings in an amount sufficient to provide the material with an electronic work function of less than 5 eV.

Neither *Ajayan et al.*, *Hiura et al.*, or *Satishkumar et al.* disclose, or even suggest, at least the above-mentioned aspects of claim 1 or claim 71. Thus, claims 1, 71, and those claims depending therefrom are not rendered obvious by the proposed 3-reference combination.

Applicants note, that on page 4 of the Official Action, it is asserted that:

> regarding claims 39-44 and 47-48, the limitations are viewed as product-by-process limitations. Therefore, because no difference is seen between the process of Ajayan in view of Hiura and taken with Satishkumar and that of the applicant, it is expected that the products will have equivalent properties.

The above-quoted rationale, as it would be applied to amended claims 1 and 71, is clearly incorrect.

The above-quoted process steps recited in claims 1 and 71, are not "product-by-process" limitations. Product-by-process limitations refers to process limitations which

appear in product claims. Neither claim 1 nor claim 71 are product claims. Thus, the above-quoted product-by-process rationale does not apply.

Further, as readily apparent from the plain language of claims 1 and 71, the above-quoted process steps clearly do not constitute product limitations which appear in process claims. In this regard, claim 1 clearly recites the process step of varying the amount of foreign species introduced into the nanostructure or nanotube-containing material. Similarly, claim 71 calls for a process step which includes introducing a foreign species in an amount sufficient to produce a desired effect within the material (i.e. - a decrease in work function to a level such that it is less than 5 eV). Thus, the above-quoted rationale appearing on page 4 of the Official Action is clearly not applicable to amended claims 1 and 71 for at least the reasons noted above.

With regard to claims 27-28, it is asserted on page 3 of the Official Action that:

> Official Notice is taken that sonication is a well-known and often used method of mixing nanotubes and acids to provide for efficient exposure.

Applicants challenge the above-noted assertion and request that the Examiner provide documentary evidence of the same such that the scope and content of the prior art, and differences with the presently claimed invention, can be evaluated according to the factors set forth in *Graham v. John Deere*. See, MPEP §2144.03(C) ("if applicant adequately traverses the Examiner's assertion of Official Notice, the Examiner must provide documentary evidence in the next Office Action if the rejection is to be maintained").

It is further noted that, with regard to claims 45-46, it is asserted on pages 4-5 of the Official Action that:

> The use of a specific range concerning the amount of intercalant deposited in the carbon nanotubes is seen to be the optimization of a known process, which could have been determined through routine experimentation and which is held to be obvious by *In re Boesch*, 205 USPQ 215.

This assertion is respectfully traversed. Contrary to the above-quoted assertion, the "optimization" rationale is clearly inexplicable to the current circumstances. The guidelines established by the Manual of Patent Examining Procedure clearly indicate that the use of this rationale under the current circumstances is inappropriate. Namely, as clearly set forth in MPEP §2144.05II.(B.):

> A particular parameter must first be recognized as a result-effective variable, i.e. - a variable which achieves a recognized result, before the determination of the optimum or workable ranges of said variable might be characterized as routine experimentation.

Under the current grounds for rejection, neither *Ajayan et al.*, *Hiura et al.*, nor *Satishkumar et al.* recognized that the electronic work function, electronic density of state at the Fermi level, or electrical conductivity of the material can be effected by the amount of foreign species intercalated into a nanostructure or nanotube-containing material. Thus, since the applied prior art lacks this recognition, the "optimization" rationale is clearly misplaced. See, *In re Antonie*, 559 F.2d 618, 195 USPQ 6 (CCPA 1977).

Claims 4, 17-19, 35, 52 and 63-64 stand rejected under 35 U.S.C. §103(a) as being obvious *Ajayan et al.* in view of *Hiura et al.* and *Satishkumar et al.*, as applied to claims 1 and 49, and further in view of U.S. Patent No. 6,283,812 to Jin et al. (hereafter "*Jin et*

al.") on the grounds set forth on pages 5-6 of the Official Action. This rejection is respectfully traversed.

Jin et al. is cited as allegedly teaching providing an array of nanotubes which contain a high directional density and thus efficient field emission properties, and teaching a means of growing aligned carbon nanotubes including CVD, arch discharge, and laser ablation.

However, even if the proposed 4-reference combination were appropriate, which it is not, the claimed invention would not result. Namely, the proposed addition of the teachings of *Jin et al.* fail to cure the previously noted deficiencies noted in connection with the principal 3-reference combination of *Ajayan et al.*, *Hiura et al.*, and *Satishkumar et al.* Thus, reconsideration and withdrawal of the above rejection is respectfully requested.

Claim 5 stands rejected under 35 U.S.C. §103(a) as being obvious over *Ajayan et al.*, *Hiura et al.*, and *Satishkumar et al.*, as applied to claim 1 above, and further in view of U.S. Patent No. 5,951,832 to Tanaka et al. (hereafter "*Tanaka et al.*) on the grounds set forth on pages 6-7 of the Official Action.

Tanaka et al. is cited as allegedly teaching intercalation of a giant fullerene structure with a foreign species. However, even if the proposed 4-reference combination were appropriate, the claimed invention would still not result. Namely, *Tanaka et al.* fails to cure the previously noted deficiencies noted in connection with the principal 3-reference combination applied to claim 1. Thus, reconsideration and withdrawal of the rejection is respectfully requested.

Claim 6 stands rejected under 35 U.S.C. §103(a) as being obvious over *Ajayan et al.*, and *Satishkumar et al.,* and further in view of U.S. Patent No. 6,057,637 to Zettl et al. (hereafter " *Zettl et al.*) on the grounds set forth on page 7 of the Official Action. This rejection is respectfully traversed.

Zettl et al. is cited as allegedly teaching the intercalation of derivative carbon nanotubes with a foreign species. However, even if the proposed 4-reference combination were appropriate, the claimed invention would still not result. Namely, *Zettl et al.* fails to cure the previously noted deficiencies discussed above in connection with the principal 3-reference combination. Thus, reconsideration and withdrawal of the rejection is respectfully requested.

Claims 7-8 stand rejected under 35 U.S.C. §103(a) as being obvious over *Ajayan et al.*, *Hiura et al.*, and *Satishkumar et al.*, as applied to claim 1 above, and further in view of U.S. Patent No. 6,217,843 to Homyonfer et al. (hereafter "*Homyonfer et al.*") on the grounds set forth on page 7 of the Official Action. This rejection is respectfully traversed.

Homyonfer et al. is cited as allegedly teaching the intercalation of inorganic fullerene-like structures, such as nested fullerenes and nanotubes, with a foreign species. However, even if the proposed 4-reference combination were appropriate, the claimed invention would still not result. Namely, the addition of the teachings of *Homyonfer et al.* fail to cure the above-noted deficiencies discussed in connection with the principal 3-reference combination. Thus, reconsideration and withdrawal of the rejection is respectfully requested.

Claims 9 and 16 stand rejected under 35 U.S.C. §103(a) as being obvious over *Ajayan et al.* in view of *Hiura et al.* and *Satishkumar et al.*, as applied to claim 1 above, and further in view of the article entitled "*Electrochemical Intercalation of Single-Walled Carbon Nanotubes with Lithium*" by Gao et al. (hereafter "*Gao et al.*") on the grounds set forth on page 8 of the Official Action. This rejection is respectfully traversed.

Gao et al. is cited as allegedly teaching purification of raw nanostructure or nanotube-containing material by filtration, as well as the step of milling the purified material to create openings therein for accepting the foreign species. However, the proposed 4-reference combination is clearly inappropriate in that it picks and chooses from amongst portions of the teachings contained in each reference, while improperly failing to consider the teachings of each of the prior art references when properly considered as a whole.

For example, the only technique taught by *Satishkumar et al.* for forming a passivation layer which closes a filled nanotube relies upon a reaction between a solvent (e.g. - methanol, ethylene glycol and propylene glycol) and carboxy and hydroxy groups present on nanotubes which were opened by treatment with nitric acid. Thus, according to the teachings of *Satishkumar et al.*, one of ordinary skill in the art would have been led to believe that it was necessary to open the nanotubes with a nitric acid treatment, such that the closing technique taught by *Satishkumar et al.* could take place.

The above-mentioned teaching is in clear contradiction with the teachings of *Gao et al.*, and the overall rationale of the proposed 4-reference combination. In particular, *Gao et al.* teaches, and is relied upon for, the notion that carbon nanotubes can be opened by

mechanical milling techniques. However, in light of the teachings of *Satishkumar et al.*, one of ordinary skill in the art would not have had a reasonable expectation of success in closing milled nanotubes with the solvent-contacting technique taught by *Satishkumar et al.* Thus, the proposed combination is clearly inappropriate.

Moreover, the grounds for rejection fail to address how the proposed 4-reference combination adequately discloses, or suggest, each and every aspect of amended claim 1.

For at least the reasons noted above, reconsideration and withdrawal of the rejection is respectfully requested.

Claims 12-13 stand rejected under 35 U.S.C. §103(a) as being obvious over *Ajayan et al.*, *Hiura et al.* and *Satishkumar et al.*, as applied to claim 1 above, and further in view of U.S. Patent No. 5,641,466 to Ebbesen et al. (hereafter "*Ebbesen et al.*") on the grounds set forth on pages 8-9 of the Official Action. This rejection is respectfully traversed.

Ebbesen et al. is cited as allegedly teaching that hydrogen peroxide is usual as a purification agent. However, even if the proposed 4-reference combination were appropriate, the claimed invention would still not result. Namely, *Ebbesen et al.* fails to cure at least the previously noted deficiencies noted in connection with the principal 3-reference combination. Thus, reconsideration and withdrawal of the rejection is respectfully requested.

Claim 14 stands rejected under 35 U.S.C. §103(a) as being obvious over *Ajayan et al.*, *Hiura et al.*, *Satishkumar et al.*, and *Ebbesen et al.*, as applied above, and further in view of U.S. Patent No. 6,413,487 to Resasco et al. (hereafter "*Resasco et al.*") on the

grounds set forth on pages 9-10 of the Official Action. This rejection is respectfully traversed.

Resasco et al. is cited as allegedly teaching the burning off of amorphous carbon by heating under a combustion gas containing oxygen. However, this 5-reference combination is clearly an example of an inappropriate hindsight reconstruction of the prior art wherein bits and pieces of the prior art have been put together with the benefit of applicant's disclosed invention. Moreover, *Resasco et al.* clearly fails to cure the previously noted deficiencies, as discussed above in connection with the principal 3-reference combination.

Claim 34 stands rejected under 35 U.S.C. §103(a) as being over *Ajayan et al.*, *Hiura et al.* and *Satishkumar et al.*, as applied to claim 1 above, and further in view of the article entitled "*Fullerene Pipes*" by Liu et al. (hereafter "*Liu et al.*") on the grounds set forth on page 10 of the Official Action. This rejection is respectfully traversed.

Liu et al. is cited as disclosing a method of washing nanotubes in order to ensure that cut nanotube pieces are perfected and chemically clean. However, even if the proposed 4-reference combination were appropriate, which it is not, reconsideration and withdrawal of the rejection is in order for reasons along the lines of those previously set forth above.

Claims 22, 24-25 and 36-38 stand rejected under 35 U.S.C. §103(a) as being obvious over *Ajayan et al.*, *Hiura et al.* and *Satishkumar et al.*, as applied to claim 1 above, and further in view of U.S. Patent No. 6,090,363 to Green et al. (hereafter "*Green et al.*") on the grounds set forth on pages 10-11 of the Official Action. This rejection is respectfully traversed.

Green et al. is cited as allegedly teaching usefulness of including elements such as Mg, Ca, Sr and Ba as foreign species. However, even if the proposed 4-reference combination were appropriate, which it is not, the presently claimed invention would still not result. Namely, *Green et al.* fails to cure the previously noted deficiencies as discussed above in connection with the principal 3-reference combination. Thus, reconsideration and withdrawal of the rejection is respectfully requested.

Claims 29-30 stand rejected under 35 U.S.C. §103(a) as being obvious over *Ajayan et al.*, *Hiura et al.* and *Satishkumar et al.*, as applied to claim 1 above, and further in view of the U.S. Patent No. 6,129,901 to Moskovits et al. (hereafter "*Moskovits et al.*") on the grounds set forth on page 11 of the Official Action. This rejection is respectfully traversed.

Moskovits et al. is cited as allegedly teaching a method of filling nanotubes whereby a reaction containing the foreign species and the nanotube material takes place. *Moskovits et al.* is also cited as allegedly teaching filling of nanotubes by electrochemical deposition. However, even if the proposed 4-reference combination were appropriate, the claimed invention would not result. Namely, *Moskovits et al.* fails to cure the previously noted deficiencies noted in connection with the principal 3-reference combination. Thus, reconsideration and withdrawal of the rejection is respectfully requested.

Claims 53-59, 61 and 62 stand rejected under 35 U.S.C. §103(a) as being obvious over *Jin et al.*, in view of *Ajayan et al.*, and further in view of *Satishkumar et al.*, on the grounds set forth on pages 12-13 of the Official Action. This rejection is respectfully traversed.

Contrary to the assertions contained on page 12 of the Official Action, the proposed 3-reference combination fails to suggest the method as defined by claim 53, and in fact teaches away from the method recited therein.

Jin et al. teaches a process for fabricating an article comprising a line truncated carbon nanotubes. The express objective of the process taught by *Jin et al.* is the formation of open and uncapped carbon nanotubes. *Jin et al.* teaches that these open or uncapped carbon nanotubes provide superior field emission properties when compared with closed or "capped" nanotubes. In this regard, *Jin et al.* teaches:

> In particular, the nanotube ends tend to be capped by metal particles or relatively large regions of carbon, and the nanotubes themselves exhibit non-uniform height . . . the capped ends tend to reduce the field concentration compared to open, e.g. broken ends or carbon-terminated spherical ends of small diameter . . . (column 3, lines 9-16)
>
> If desired, any remnant, metal coating or debris near the truncated nanotube ends are acid-dissolved to expose clean, truncated tips. (Column 6, lines 49-51).

As readily apparent from the above, one of ordinary skill in the art would not have led to a process which includes the closing of opened nanotubes by the formation of passivation layers on the ends thereof. To do so is clearly contradictory to the express purpose of *Jin et al.* Thus, one of ordinary skill in the art would not have considered combining the three references in the manner proposed.

For at least the reasons noted above, the rejection is improper and should be withdrawn.

For similar reasons, claims 54-59, 61 and 62, which depend from claim 53, are also clearly not rendered obvious by the proposed combination.

With regard to claim 62, it is alleged on page 13 of the Official Action that:

> Official Notice is taken by the Examiner that hydrogen plasma is known to be useful for the cleaning of electron emitting carbon structures.

Applicants challenge the above-quoted assertion and respectfully request that documentary evidence be provided int he next Official Action in support of the above-quoted assertion, so that the scope and content of the prior art and any differences between the prior art and the presently claimed invention can be properly considered under the *Graham v. Deere* framework.

ALLOWABLE SUBJECT MATTER

Applicants note with appreciation the indication that claim 33 would be considered allowable if rewritten in independent form including all the limitations of the base claim and any intervening claims. By the present response, applicant has submitted newly presented claim 72 which substantially corresponds in scope to the combination of claims 1 and 33. Thus, favorable consideration of newly presented claim 72, and an indication of allowability thereof, is respectfully requested.

CONCLUSION

From the foregoing, further and favorable action in the form of a Notice of Allowance is earnestly solicited. Should the Examiner feel that any issues remain, it is

requested that the undersigned be contacted so that any such issues may be adequately addressed and prosecution of the instant application expedited.

Respectfully submitted,

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